EVALUATING THE MILLING, COOKING, AND PROCESSING CHARACTERISTICS REQUIRED OF RICE VARIETIES IN THE UNITED STATES

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EVALUATING THE MILLING, COOKING, AND PROCESSING CHARACTERISTICS REQUIRED OF RICE VARIETIES IN THE UNITED STATES [1]

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INTRODUCTION

A detailed description of techniques and methods of evaluating rice milling, cooking, and processing characteristics in rice breeding programs in the United States was outlined by Webb (*1967a*).[3] In general, the same techniques and methods are in use today except for some changes in emphasis in certain testing areas. These changes are updated in this report.

Historically, rice varieties in the United States are classed as short- (Pearl), medium-, and long-grain types which are associated with specific cooking and processing characteristics. Raw milled kernels of highquality, domestic, long-grain varieties, frequently called "hard-rice," usually cook dry and fluffy and the cooked grains tend to remain separate. On the other hand, high-quality short- and medium-grain varieties, called "soft-rice," cook moist and firm and the cooked grains tend to stick or clump together.

All three grain types with their characteristic textural qualities are in rather widespread demand by the domestic and foreign trade because the different ethnic groups prefer the various textures in home-boiled rice. Processors of rice also require all grain types and textural qualities for use in various kinds of prepared and convenience-type ricecontaining food products, such as parboiled rice, quick-cooking rice, dry breakfast cereals, canned rice, canned soups, dry soup mixes, baby foods, and frozen dishes. Annually, in the United States, a substantial and increasing amount of the domestic rice crop is processed and reprocessed into these numerous kinds of prepared products. There is a strong demand for the broken grades of rice in brewing, and rice flour is used in various prepared mixes. In many of these processed and convenience foods, the textural qualities and grain size of United States long-grain varieties are preferred, while in other foods the qualities of the short- and medium-grain types are required for their specific uses. Hence, the domestic and world trade associates United States long-, medium-, and short-grain rice with certain specific cooking and processing characteristics, and for this reason new varieties must have the same (or improved) milling, cooking and processing characteristics as the established varieties they replace.

QUALITY TESTING PROGRAM

The determination and evaluation of the milling, cooking, and processing characteristics of parental material, hybrid progeny, breeding lines, and new varieties of rice are an essential part of the coordinated rice breeding program conducted by the United States Department of Agriculture and the agricultural experiment stations in the rice-producing States of Arkansas, California, Louisiana, Mississippi, and Texas. New varieties developed in these programs and released for commercial

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[3] References to Literature Cited, p. 7, are herein indicated by the name of the author or authors followed by the year of publication in italic.

production must meet established standards for the milling, cooking, and processing characteristics required of their particular grain type. These characteristics are determined and evaluated at the Regional Rice Quality Laboratory.

The Regional Rice Quality Laboratory was established in 1955 at the Texas A&M University Agricultural Research and Extension Center, Beaumont, and is operated by the Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Texas Agricultural Experiment Station and the Texas Rice Improvement Association. This Laboratory serves the coordinated rice breeding and genetics program conducted cooperatively by the U.S. Department of Agriculture and the agricultural experiment stations in Arkansas, California, Louisiana, Mississippi, and Texas. The program is also supported in part by grants-in-aid from Campbell Soup Company, New Jersey, and General Foods Corporation, Delaware and New York.

The first stage of evaluation involves the quality of parental material, followed by early generation progeny testing and by continued evaluation through every stage of development leading up to the release as outlined by Johnston (*1967*). Before release for commercial production, each new variety is tested agronomically and for quality for at least 3 years over its likely production area. This practice is carried out through the Uniform Rice Performance Nurseries and other trials in each of the rice-producing States. These trials provide an essential means of evaluating the quality performance of each new variety over a wide range of environmental and modifying influences such as soil and climatic conditions. Finally, grain of the new variety is sent to leading processors and reprocessors of rice for their product evaluation.

MILLING QUALITY EVALUATION

Adair and others (*1966a*) reviewed the importance and methodology of evaluating rice milling yields. According to these investigators, the milling quality of rice is based largely on the outturn of whole kernel milled rice obtained because this is usually the product of greatest economic value. Yields of whole kernel milled rice also vary widely, depending on many factors such as variety, grain type, cultural practices and other environmental factors, and drying, storing, and milling conditions. The yield of total milled rice (whole kernel and all sizes of broken kernels) is important too and this yield is further influenced by the proportion of hulls and the amount of fine endosperm particles unavoidably included in the bran fraction during the milling process.

Because many factors affect milling quality, rigid laboratory milling tests are required to insure that any new variety released will consistently produce high yields of whole kernel and total milled rice. Three methods are used in United States breeding programs to evaluate the milling quality of rice varieties and selections (Adair and others, *1966a*). The method used depends on the amount of rice available for testing. The official grading method, described by the United States Rice Grading Service, for determining the milling quality of rough rice gives the breeder comparative information regarding milling quality of the more advanced selections. This method requires 1,000 grams of rough rice for each determination.

A modification of the official method requires only 125 grams of rough rice and enables the breeder to check milling quality at very early stages of development (Beachell and Halick, *1957*). This method is described in detail by Adair and others (*1966a*).

A test-tube method is available for milling very small samples (Scott, Webb, and Beachell, *1964*) and can be used to mill the rice from only one panicle. This method of milling small samples gives a rough indication of the potential milling quality of individual plant selections and also provides a milled sample to use for early generation evaluation of cooking and processing characteristics.

The use of this combination of laboratory milling methods enables rice breeders to develop new varieties of high milling quality.

COOKING AND PROCESSING QUALITY EVALUATION

Specific criteria[4] are used to describe the cooking and processing characteristics required in new varieties of each grain type. These criteria are based on results of a series of chemical and physical tests that, when taken together, serve as indices of rice cooking and processing behavior. Selections and new varieties are systematically tested for amylose content (Williams and others, *1958*, as modified by Juliano, *1971*); alkali reaction of whole kernel milled rice in contact with dilute alkali—a measure of gelatinization temperature (Little, Hilder, and Dawson, *1958*); water uptake capacity at 77° C. (Halick and Kelly, *1959*); birefrigence-end-point temperature (BEPT) (Halick and others, *1960*); amylographic gelatinization and pasting characteristics (Halick and Kelly, *1959*); protein content (Pickney, *1961*; AACC, *1962*; Webb, *1964*; Parial, Rooney, and Webb, *1970*); parboil canning stability (Webb and Adair, *1970*); and cookability of rice with malt (Webb, *1963*). Test values for these characteristics are established for all commercially acceptable varieties; hence the characteristics of new varieties can be compared directly with those of standard varieties.

In rice breeding programs the milling, cooking, and processing characteristics of new varieties are always compared with those of comparably grown leading commercial varieties according to the format illustrated in figure 1. If the properties of the new varieties are the same as or superior to those of the preferred varieties, they are considered to have high quality; if not, they are considered to have undesirable or unknown quality. By means of comparative test data accumulated on new and standard varieties grown over a period of years at several locations, the relative qualities of the new varieties can be described. The form illustrated in figure 1 is used primarily for describing the cooking and processing characteristics of advanced experimental and potentially new commercial varieties. For describing the characteristics of early generation material as well as advanced selections, the amylose content, or related test indicative of amylose content, is considered to be the single most important characteristic measured. Next, and almost as important, are the gelatinization characteristics measured by the alkali test. Since 1955 virtually all breeding material in the United States has been tested for those two characteristics. Now (1972) these two tests are used universally in breeding programs in many countries to describe rice cooking and processing qualities.

The value of characterizing rice cooking and processing characteristics in terms of specific physicochemical properties has been clearly demonstrated. It has enabled rice breeders in the United States to develop and release new varieties that combine the desired cooking and processing characteristics with the agronomic features required to meet the various needs of the rice industry. Current commercial, high-quality, United States long-grain vari-

[4] These criteria are used by U.S. Department of Agriculture rice researchers in the coordinated rice breeding and genetics program but are not the basis for official U.S. Department of Agriculture marketing classes.

Rice cooking and processing quality evaluation form

Chemical and physical endosperm characteristics	Unit	Standard variety	Advanced selection or new variety
Amylose Content	Percent		
Alkali Reaction Value	Average No.		
Water Uptake at 77° C.	Ml./100 g.		
Gelatinization Temperature (BEPT)[1]	° C.		
Amylographic Paste Viscosity:			
Peak-Brabender Units	B.U.		
Cooked 10 Min. at 95° C.	B.U.		
Cooled at 50° C.	B.U.		
Cookability of Rice With Malt:			
Viscosity Flow Time	Sec./150 ml.		
Parboil-Canning Stability:			
Dry-Matter (Solids) Loss	Percent		
Biuret Protein Value	Percent transmission		
Crude Protein (N × 5.95)	Percent		

[1] (BEPT) Birefringence-end-point-temperature.

Figure 1.—Form used to describe cooking and processing characterics of rice varieties.

eties that have been developed by using these quality test results are Belle Patna (Beachell and others, *1961*), Bluebelle (Bollich and others, *1966b*), Dawn (Bollich and others, *1966a*), Starbonnet (Johnston and others, *1967*), and Labelle (Bollich and others, *1972*). Current commercial medium-grain varieties include Saturn (Jodon and Atkins, *1964*), Nova 66 (Johnston and others, *1966*), and Vista (Jodon, Sonnier, and McIlrath, *1971*).

Inheritance studies indicate that amylose and alkali values have a relatively high level of heritability (Beachell and Halick, *1957*; Adair and others, *1966a*; Bollich and Webb, *1966*). Thus, in rice breeding programs in the United States, these characteristics are selected for and "fixed" in very early stages of development of the new varieties of rice. For example, selection for amylose and alkali values of Starbonnet and Labelle began approximately 8 years before they were commercially released. Specific characteristics of other varieties were selected in a similar manner, depending on results of the quality tests conducted. Hence, at the present time rice breeders in each of the rice-producting states are now selecting for the qualities that will appear in new varieties to be released in future years.

CHEMICAL AND PHYSICAL (QUALITY) CHARACTERISTICS OF SELECTED RICE VARIETIES IN THE UNITED STATES

A number of comparative chemical and physical (quality) characteristics of some typical and non-typical cooking United States varieties of rice are tabulated in table 1. The typical cooking long-, medium-, and short-grain varieties selected as standards for comparison are Belle Patna, Nato, and Caloro, respectively. The data presented are average values from representative samples of each variety grown in the Uniform Rice Performance Nurseries and other trials in Arkansas, Louisiana, Mississippi, and Texas. Environmental and other factors influence these characteristics to some extent; however, within a limited range, the values shown are representative of each variety.

Some chemical and physical characteristics associated with the typical cooking United States long-grain varieties shown in table 1 are: a relatively high amylose content, a slight to moderate reaction of "head" rice in contack with dilute alkali (alkali reaction); a moderate water-uptake capacity at 77° C.; and an intermediate gelatinization temperature (BEPT). Amylograms of the typical long-grain varieties usually show an intermediate peak viscosity and a relatively high cooked paste viscosity on cooling to 50° C. The parboil-canning characteristics of the typical long-grain varieties, as compared with those of the medium- and short-grain varieties, show relatively low losses of solids during processing, and the canned kernels show a minimum amount of splitting and fraying of edges and ends.

Some chemical and physical characteristics associated with the typical cooking medium- and short-grain varieties shown in table 1 are: a relatively low amylose content; a pronounced and extensive reaction of "head" rice in contact with dilute alkali (alkali reaction); a relatively high water-uptake capacity at 77° C.; and a relatively low gelatinization temperature (BEPT). Amylograms of the typical short- and medium-grain varieties usually show relatively low cooked paste viscosities on cooling to 50° C. The parboil-canning characteristics of the typical short- and medium-grain varieties, as compared directly with those of the preferred long-grain varieties, show relatively high losses of solids during processing, and the canned kernels show extensive splitting and fraying of edges and ends.

Although in the United States each major grain type has been generally associated with specific cooking and processing characteristics, certain non-typical varietal exceptions within each grain type occurred before the establishment of the quality testing program. Notable among these were the non-typical (table 1) cooking and processing characteristics with respect to grain type of the long-grain varieties Century Patna 231 and Toro and the medium-grain variety Early Prolific. Measured differences in their chemical and physical properties have been reported (Halick and Kelly, *1959*; Williams and others, *1958*; Adair and others, *1966a*).

For example, the amylose content, alkali reaction value, gelatinization temperature, and parboil-canning stability of the long-grain variety Toro are similar to those of the typical cooking short- and medium-grain varieties. Reportedly, this variety resembles the typical cooking short- and medium-grain varieties more in cooking behavior than it does the typical cooking long-grain varieties. Of the varieties tested, the long-grain variety Century Patna

Table 1.—Comparative chemical and physical characteristics of selected rice varieties in the United States[1]

Variety	Milled rice[3]									Parboiled rice
	C.I. No.[2]	Amylose content	Alkali reaction	Water uptake at 77° C.	Gelatinization temperature (BEPT)	Amylograph viscosity: Peak	Amylograph viscosity: After 10 minutes at 95° C.	Amylograph viscosity: Cool to 50° C.	Crude protein (N × 5.95)	Parboil-canning dry-matter (solids) loss
		Percent	*Average No.*	*Ml./100 g.*	*(° C.)*	*Brabender units*	*Brabender units*	*Brabender units*	*Percent*	*Percent*
LONG-GRAIN										
Typical cooking varieties:										
Belle Patna (standard)	9433	23.8	3.6	130	73	820	410	790	6.9	19
Bluebelle	9544	24.1	3.7	124	74	820	430	860	6.7	18
Bluebonnet 50	8990	23.7	4.1	136	72	815	400	770	6.8	20
Dawn	9534	25.1	3.9	130	73	765	415	830	6.9	21
Labelle	9708	24.8	3.5	125	73	820	410	810	6.3	19
Starbonnet	9584	25.0	3.4	122	72	840	400	780	6.1	20
Vegold	9385	24.6	3.7	127	74	850	430	820	6.7	20
Della (aromatic type)	9483	23.6	3.9	128	72	800	410	780	6.9	21
Nontypical cooking varieties:										
Century Patna 231	8993	16.2	2.2	97	79	1040	430	740	6.0	36
Toro	9013	16.5	6.7	399	66	915	380	660	6.3	35
MEDIUM-GRAIN										
Typical cooking varieties:										
Calrose	8988	19.0	7.0	340	65	960	400	680	6.3	33
CS-M3	9675	18.4	6.8	332	67	980	420	750	6.2	33
Earlirose	9672	18.6	6.4	350	66	840	430	730	6.8	32
Kokaho Rose	9673	18.2	7.0	310	68	880	430	710	6.6	34
Nato (standard)	8998	15.3	6.3	316	67	940	410	720	6.4	34
Nova 66	9481	15.8	6.3	320	66	960	390	720	6.3	36
Saturn	9540	15.2	6.2	300	68	970	420	760	6.5	31
Vista	9628-2	17.0	6.5	340	65	890	370	740	6.4	32
Nontypical cooking variety:										
Early Prolific	5883	14.8	2.6	92	78	1020	390	700	6.2	34
SHORT-GRAIN										
Typical cooking varieties:										
Caloro (standard)	1561-1	19.0	7.0	360	66	850	390	690	6.0	32
Colusa	1600	18.0	6.5	350	66	840	400	690	5.9	30
CS-S4	9835	18.4	7.0	320	67	820	370	680	6.0	33
Nortai	9836	18.8	6.7	310	67	870	380	680	6.2	31

[1] Results of tests conducted at the Regional Rice Quality Laboratory, Beaumont, Tex. Values are averages of representative samples grown in the Uniform Rice Performance Nurseries and other trials in Arkansas, Louisiana, Mississippi, and Texas. Data on samples grown in California are not included. Data taken in part from Adair and others (*1966a*); Bollich and others (*1966a, 1972*);, Johnston and others (*1963, 1966, 1967*); and Webb (*1967a, 1967b*).

[2] C.I. refers to the accession number used in the Plant Genetics Research Lab., Plant Genetics and Germplasm Institute, Agricultural Research Service, U.S. Department of Agriculture.

[3] Milled rice moisture content was 11.5 percent.

231 and the medium-grain variety Early Prolific had the highest gelatinization temperature and were the most resistant to the action of dilute alkali. In general, these varieties were not widely accepted for use in cooked rice and processed products. Now in the coordinated rice breeding program, through planned breeding, no new variety is seriously considered for release unless it meets the cooking and processing standards required for its particular grain type.

Some advantages for having only one cooking type within each major grain type are (1) ease of identification at all stages of processing and (2) minimizing requirements for separate storage and handling facilities. However, having only one cooking type within each major grain type greatly restricts the various cooking types that otherwise might be available to the rice industry.

DISCUSSION

Although the chemical and physical characteristics of rice described have been invaluable in evaluating and characterizing the cooking and processing characteristics of rice in the United States, they do not always explain the fundamental cause or reason for the observed differences in rice cooking and processing behavior.

For example, why do rice varieties of similar amylose content and other measured characteristics have substantially different parboil-canning stability? Also, why do varieties of similar measured characteristics differ markedly in their suitability for specific brewing needs? To answer these and other questions, basic research on the factors influencing and constituents responsible for known differences in milling, cooking, and processing behavior is essential because this information would accelerate breeding rice for improved quality. Also, as new uses of rice are developed and as improved techniques in rice processing become available, the qualities now desired may change or need modification. Consequently, in United States rice breeding programs, constant attention must be given to all aspects of rice quality.

The nutritive quality of rice is very important, and investigations have been in progress for several years in the United States to improve the inherent nutritional value of rice—particularly with respect to protein content and quality (Johnston, *1961*). Rice protein evaluation is conducted principally at the Cereals Protein Laboratory at Beltsville, Md., and Adair and others (*1966b*) and Adair and Webb (*1971*) outlined the progress made and discussed future trends in breeding rice for higher protein content and quality in the United States.

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